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New records of smut fungi. 7

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Abstract — Three new species of smut fungi from North America are described and illustrated: *Anthracoidea deweyanae* on *Carex deweyana* from U.S.A., *A. foeneae* on *Carex foenea* from Canada, and *A. savilei* on *Carex norvegica* from Canada. *Anthracoidea shaanxiensis* is reported for the first time from North America (Canada) on a new host plant, *Carex concinna*. This species has been known only from Chinese localities.

Key words — *Anthracoideaceae,* taxonomy, *Ustilaginomycetes*

Introduction

A revision of *Anthracoidea* specimens, on loan from the National Mycological Herbarium, Agriculture and Agri-Food Canada (DAOM), yielded three new records for Canada and one for U.S.A. For each of those countries, 32 *Anthracoidea* species have been recorded to date (Denchev & Denchev 2011; Vánky 2011a,b; Vánky & Salo 2011). We propose three new species of *Anthracoidea* on *Carex* spp. from sections *Deweyanae, Ovales,* and *Racemosae,* based on the fact that *Anthracoidea* species are restricted to host plants in the same or closely related *Carex* sections (Vánky 1979).

Material & methods

Dried specimens from DAOM were examined under light (LM) and scanning electron (SEM) microscopes. For LM observations, spores were mounted in lactophenol solution on glass slides, gently heated to boiling point to rehydrate the spores, and then cooled. Spore measurements are given in the form: min–max (extreme values, if necessary) [mean ± 1 standard deviation]. For SEM, spores were attached to specimen holders by double-sided adhesive tape and coated with gold with an ion sputter. The surface structure of spores was observed at 10 kV and photographed with a JEOL JSM-5510 scanning electron microscope.

New records

Anthracoidea deweyanae Denchev & T. Denchev, **sp. nov.** Figs 1–4

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Differs from all other *Anthracoidea* species by specialization on *Carex* sect. *Deweyanae.*

Type: on *Carex deweyana* Schwein.: U.S.A., California, Tehama Co., Brokeoff Mountain Trail, Lassen Volcanic National Park, 18 August 1957, leg. W.B. & V.G. Cooke, no. 30919 (**holotype,** DAOM 167 093).

Etymology: the name refers to the host species.

Sori in ovaries, scattered in the inflorescence, as broadly ellipsoidal or subglobose, black, hard bodies, 1.5–2.5 mm long, when young covered by a thin membrane, later becoming exposed; spore mass of the mature sori powdery on the surface. Spores flattened, in plane view orbicular, suborbicular, broadly elliptical or oval, sometimes slightly irregular, in plane view 17–21.5 × 15–20.5 [19.3 ± 0.9 × 17.6 ± 1.2] µm (n = 100), in side view 11.5–13.5 µm thick, medium reddish brown, wall more or less evenly thickened, 1.0–1.4 µm thick, sometimes 1–3 internal swellings present, light-refractive spots absent; in LM verruculose, warts up to 0.3 µm high, spore profile not or slightly affected. Spore germination unknown.

Distribution — On *Cyperaceae: Carex* sect. *Deweyanae: Carex deweyana.*

Comments — *Carex deweyana* is a North American species, distributed in Canada and U.S.A. It belongs to *Carex* sect. *Deweyanae,* which includes eight species from North America and East Asia (Naczi 2002, 2009). As no *Anthracoidea* species has previously been reported on a representative of that section, we propose a new species.

Anthracoidea foeneae Denchev & T. Denchev, **sp. nov.** Figs 5–8

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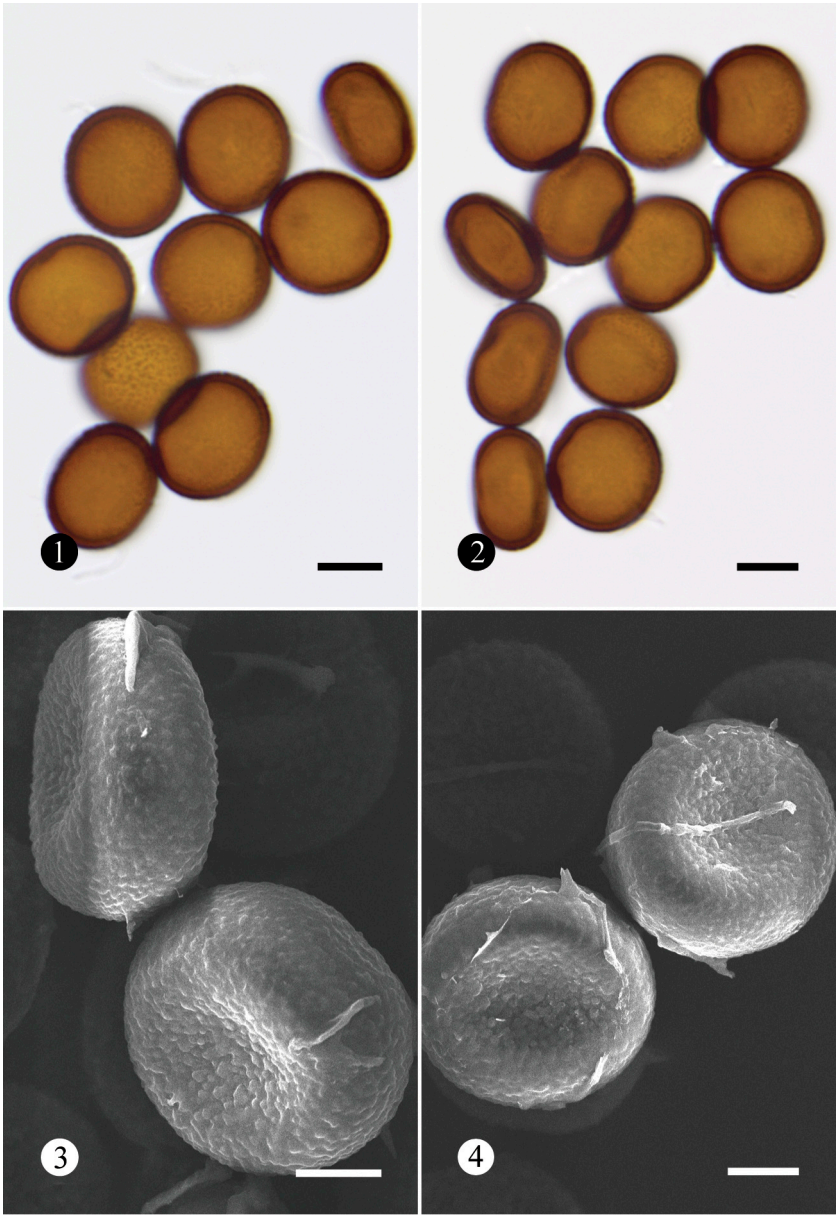
Differs from other *Anthracoidea* species on sedges in *Carex* sect. *Ovales* by having a spore wall 1.3–3.0(–3.5) µm thick, lacking internal swellings and light-refractive spots, and having verruculose ornamentation, with warts up to 0.3 µm high.

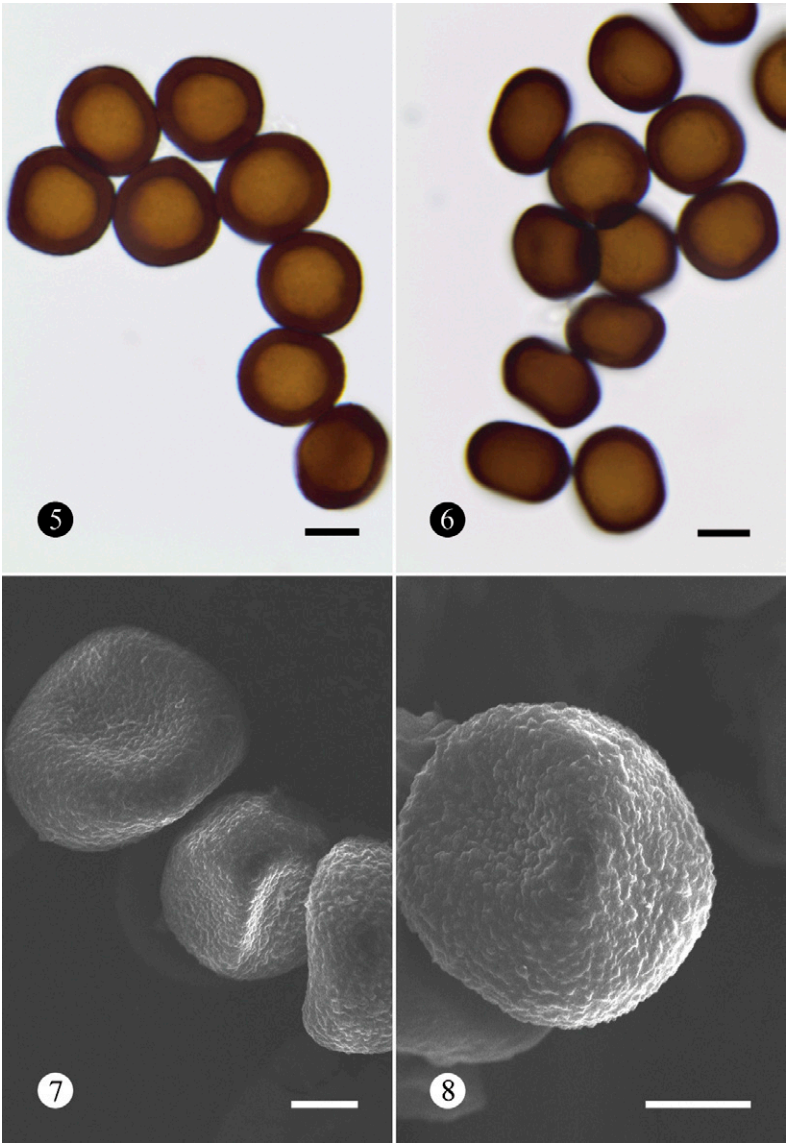
Type: on *Carex foenea* Willd.: Canada, Ontario, Constance Bay, 30 June 1938, leg. I.L. Conners (**holotype,** DAOM 18 137).

Etymology: the name refers to the host species.

Sori in ovaries, scattered in the inflorescence, as broadly ellipsoidal, ovoid or subglobose, black, hard bodies, 1.7–3.0 mm long, when young covered by a thin membrane, later becoming exposed; spore mass of the mature sori powdery on the surface. Spores flattened, in plane view broadly elliptical, slightly irregular, suborbicular, orbicular or oval, in plane view 16–22 × 14.5–20.5 [19.0 ± 1.3 × 17.2 ± 1.4] µm (n = 100), in side view 11.5–14 µm thick, middle to dark reddish brown, wall slightly unevenly thickened, 1.3–3.0(–3.5) µm thick, internal swellings, protuberances, and light-refractive spots absent; in LM



Figs 1–4. *Anthracoidea deweyanae* on *Carex deweyana* (DAOM 167 093). Spores in LM and SEM. Scale bars: 1, 2 = 10 µm; 3, 4 = 5 µm.



Figs 5–8. *Anthracoidea foeneae* on *Carex foenea* (DAOM 18 137). Spores in LM and SEM. Scale bars: 5, 6 = 10 µm; 7, 8 = 5 µm.

verruculose, warts up to 0.3 µm high, spore profile not or slightly affected. Spore germination unknown.

Distribution — On *Cyperaceae: Carex* sect. *Ovales: Carex foenea.*

Comments — *Carex foenea* (sect. *Ovales*) is a North American species distributed from the subarctic to the northern U.S.A. (Mastrogiuseppe et al. 2002). No species of *Anthracoidea* has previously been reported on that sedge. *Carex* sect. *Ovales* is the largest section in *C.* subg. *Vignea,* consisting of about 90 species, predominantly North American, but also with a number of species in mountainous areas of the neotropics and a few species found in North Africa and the temperate zone of Europe and Asia (Egorova 1999, Mastrogiuseppe et al. 2002, Reznicek et al. 2007, Dai et al. 2010).

Four *Anthracoidea* species have been previously described on sedges in section *Ovales: A. fischeri* (P. Karst.) Kukkonen, *A. kanasensis* H.C. Zhang & L. Guo, *A. uleana* (Syd. & P. Syd.) Vánky, and *A. verrucosa* (Savile) Nannf. (Vánky 2011b). *Anthracoidea uleana* differs from *A. foeneae* by a thinner wall (ca 1.0 µm) with 3–4 ring-formed thinner areas while *A. foeneae* has a uniform, up to 3.0(–3.5) µm thick wall. *Anthracoidea fischeri* has spores with echinate ornamentation, with spines up to 1.0 µm high, and a wall with 1–5 internal swellings while *A. foeneae* has verruculose ornamentation with warts ≤0.3 µm high and a wall with no internal swellings. *Anthracoidea verrucosa* is distinguished by its thinner wall (ca 1.0 µm). *Anthracoidea kanasensis* differs from *A. foeneae* by having irregular spores and well developed internal swellings.

Hipp et al. (2006) studied the phylogeny of sedges of section *Ovales* and compared them with representatives of other sections of subgenus *Vignea.* Based on a study of ITS and ETS sequences of those *Carex* species, they marked a sister group to section *Ovales,* which included species of the following sections: *Ammoglochin, Chordorrhizae, Deweyanae, Divisae, Glareosae, Holarrhenae, Phaestoglochin, Physoglochin, Remotae, Stellulatae.* Fourteen species of *Carex* from that sister group are known to be infected by *Anthracoidea* (Table 1).

Table 1. *Anthracoidea* species on sedges from sections closely related to *Ovales*.

Carex section	*Carex* species	*Anthracoidea* species
Ammoglochin	*arenaria*	*arenariae*
	brizoides	*arenariae*
Chordorrhizae	*chordorrhiza*	*aspera, fischeri*
	pseudocuraica	*fischeri*
Deweyanae	*deweyana*	*deweyanae*
Divisae	*duriuscula*	*eleocharidis*
Glareosae	*brunnescens*	*fischeri, karii*
	canescens	*fischeri, karii*
Phaestoglochin	*hoodii*	*verrucosa*
	occidentalis	*vankyi*
Physoglochin	*gynocrates*	*karii, turfosa*
Stellulatae	*echinata*	*karii*
	exilis	*turfosa*
	interior	*fischeri, karii*

All of these nine *Anthracoidea* species differ morphologically from *A. foeneae.*

Anthracoidea savilei Denchev & T. Denchev, **sp. nov.** Figs 9, 10

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Anthracoidea savilei differs from *A. atratae* and *A. buxbaumii* by smaller spores and unevenly thickened spore walls.

Type: on *Carex norvegica* Retz.: Canada, Quebec, Great Whale River, 25 July 1949, leg. D.B.O. Savile, no. 525 (**holotype,** DAOM 28 182).

Etymology: named in honour of the Canadian mycologist and botanist D.B.O. Savile (1909–2000).

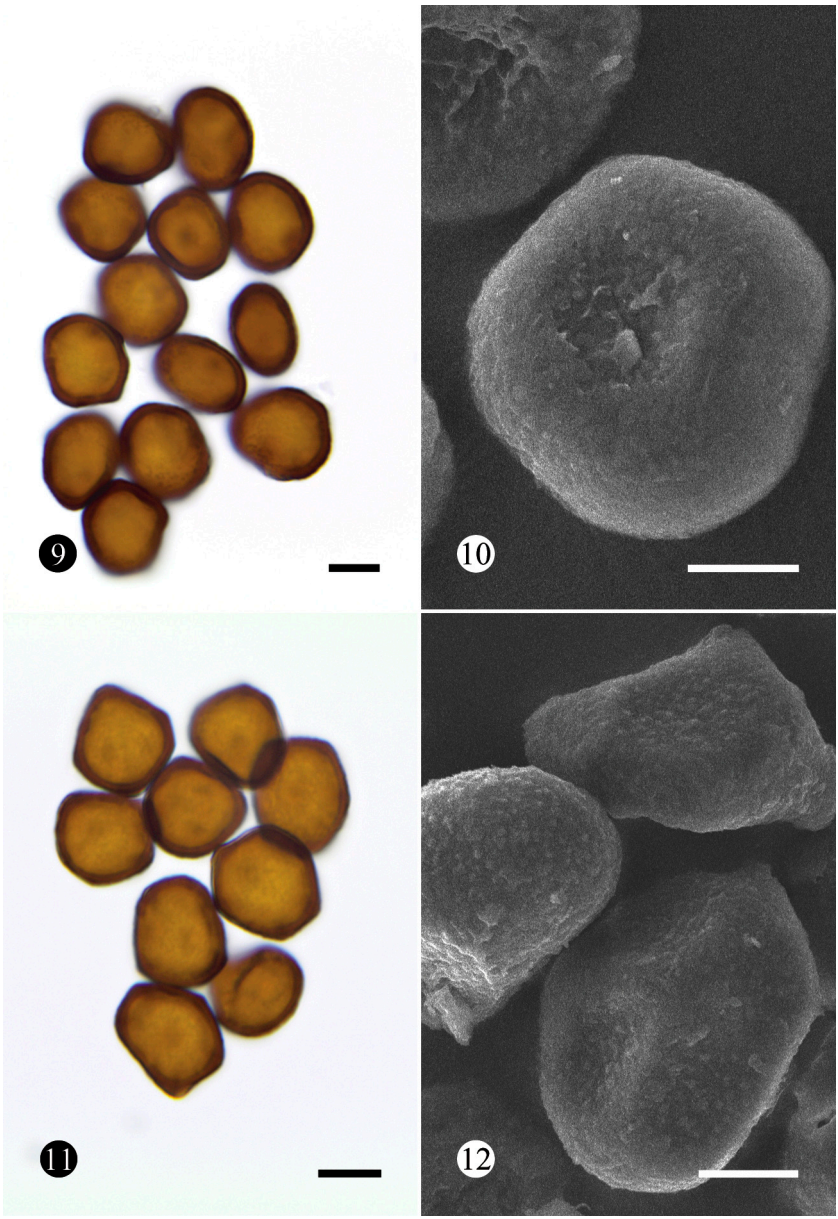
Sori in ovaries, scattered in the inflorescence, as subglobose or broadly ellipsoidal, black, hard bodies, 1.2–1.7 mm long, when young covered by a thin membrane, later becoming exposed; spore mass of the mature sori powdery on the surface. Spores flattened, in plane view slightly irregular, subpolygonal, broadly elliptical or suborbicular, in plane view (15–)16–21.5 × 12.5–19 [18.5 ± 1.3 × 15.7 ± 1.5] µm (n = 150), in side view 11–13 µm thick, medium reddish brown, wall unevenly thickened, 1.2–2.5 µm thick, thickest at the angles, with 1–3 internal swellings (sometimes conspicuous), occasionally with light-refractive spots; in LM verruculose, warts up to 0.3 µm high, spore profile not or slightly affected; in SEM verruculose, often covered by a gelatinous sheath. Spore germination unknown.

Distribution — On *Cyperaceae: Carex* sect. *Racemosae: Carex norvegica.*

Comments — *Carex norvegica* is a circumpolar arctic-montane species, distributed in Europe (the northern part and Alps), Asia (Siberia, Far East of Russia, Afghanistan, Mongolia, and the Himalayas), North America (Subarctic to eastern Canada and Montana), and Greenland. It belongs to *C.* sect. *Racemosae* G. Don, a large section within *Carex* with about 62 species in extra-tropical regions of Eurasia and North America (Egorova 1999, Murray 2002a, Dai et al. 2010). This section has commonly been named as *Atratae* (Heuffel) H. Christ (e.g., in Flora Europaea, Chater 1980) in the literature when reporting *Anthracoidea* hosts (e.g., Nannfeldt 1979, Vánky 1994, 2011b). Egorova (1999) displaced the name *Atratae* with *Microrhynchae* Drejer ex L.H. Bailey. Currently, *Racemosae* is recognized as the earliest valid name (Murray 2002a, Dai et al. 2010).

Hendrichs et al. (2004) studied seven species of *C.* sect. *Racemosae* (as *Atratae*), including *Carex atrata* (the type species of the section) and *C. norvegica.* They concluded that the section was homogeneous, and the species studied formed a well supported clade.

The following eight *Carex* species of section *Racemosae* have been previously found to be infected by *Anthracoidea* species: *C. adelostoma* V.I. Krecz. (incl. *C. buxbaumii* subsp. *alpina* (Hartm.) Liro), *C. atrata* L., *C. buxbaumii* Wahlenb., *C. gmelinii* Hook. & Arn., *C. hartmanii* Cajander, *C. heteroneura* S. Watson, *C. raynoldsii* Dewey, and *C. tarumensis* Franch.



Figs 9, 10. *Anthracoidea savilei* on *Carex norvegica* (DAOM 28 182). Spores in LM and SEM.
Figs 11, 12. *Anthracoidea shaanxiensis* on *Carex concinna* (DAOM 223 117).
Spores in LM and SEM. Scale bars: 9, 11 = 10 µm, 10, 12 = 5 µm.

Some sedges in the former section *Atratae* are currently separated in the *C.* sect. *Scitae* Kük. (Egorova 1999, Murray 2002b). The members of that section are morphologically closely related to the species in *C.* sect. *Racemosae*. The following six *Carex* species of *C.* sect. *Scitae* are known as hosts of *Anthracoidea* species: *C. flavocuspis* subsp. *krascheninnikovii* (Kom. ex V.I. Krecz.) T.V. Egorova (≡ *C. krascheninnikovii* Kom. ex V.I. Krecz.), *C. macrochaeta* C.A. Mey., *C. nesophila* Holm, *C. riishirensis* Franch. (incl. *C. koraginensis* Meinsh.), *C. podocarpa* R. Br. (incl. *C. montanensis* L.H. Bailey), and *C. spectabilis* Dewey.

Two *Anthracoidea* species have been previously described on sedges in sections *Racemosae* and *Scitae: A. atratae* (Savile) Kukkonen and *A. buxbaumii* Kukkonen. *Anthracoidea atratae* differs from *A. savilei* by having larger spores (17–25 µm long), evenly thickened walls without internal swellings, and verrucose ornamentation with higher warts (up to 0.7 µm). *Anthracoidea buxbaumii* differs from *A. savilei* by having larger spores (19–28(–30) µm long) and evenly thickened walls.

Nannfeldt (1979: 36–37) referred to five undescribed *Anthracoidea* species on sedges from sect. *Racemosae*. Among them the following ones are noteworthy: "*Anthracoidea* sp. 9" on *Carex norvegica* (based on specimens from Sweden and Finland), "*Anthracoidea* sp. 8" on *Carex holostoma* Drejer (from Canada), and "*Anthracoidea* sp. 10" on *Carex stylosa* C.A. Mey. (from Alaska). The first and second of these possess larger spores than those of *A. savilei,* while the third species is too briefly characterized to be critically compared with other *Anthracoidea* species.

Key to the *Anthracoidea* species on *Carex* sects. *Racemosae* and *Scitae*
(modified after Vánky 2011b)

1 Spores (15–)16–21.5 µm long, wall unevenly thickened, with 1–3 internal swellings (sometimes conspicuous), verruculose, warts ≤0.3 µm high. [Currently known on *C. norvegica.*] ..... ***A. savilei***

1* Spores larger, wall evenly thickened **2**

2 Spores 17–25 µm long, internal swellings lacking, verrucose, warts up to 0.7 µm high. [Currently known on *C. atrata, heteroneura, flavocuspis* subsp. *krascheninnikovii, macrochaeta, nesophila, podocarpa, raynoldsii, riishirensis,* and *spectabilis.*] ..... ***A. atratae***

2* Spores 19–28(–30) µm long, with 1–3 internal swellings, verruculose, warts ≤0.3 µm high. [Currently known on *C. adelostoma, buxbaumii, gmelinii, hartmanii,* and *tarumensis.*] ..... ***A. buxbaumii***

Anthracoidea shaanxiensis L. Guo — Figs 11, 12

Sori in ovaries, scattered in the inflorescence, as subglobose or broadly ellipsoidal, black, hard bodies, ca 1.8 mm long, when young covered by a thin membrane, later becoming exposed; spore mass of the mature sori powdery

on the surface. Spores flattened, in plane view mainly irregular, subpolygonal, sometimes broadly elliptical, in plane view 14–21.5(–23) × 11.5–17.5 [17.0 ± 1.8 × 14.2 ± 1.5] µm (n = 50), in side view 10–12 µm thick, medium reddish brown, wall unevenly thickened, 0.9–2.2 µm thick, occasionally small protuberances present, with 1–3 internal swellings, sometimes light-refractive spots present; in LM verruculose, warts up to 0.3 µm high, spore profile not affected or nearly so. Spore germination unknown.

Specimen examined — On ***Carex concinna*** R. Br.: **CANADA, Northwest Territories,** Nahanni National Park, 61°52' N, 126°37' W, 570 m, 9 July 1976, leg. S. Talbot, no. T 6038-13 (DAOM 223 117).

Distribution — On *Cyperaceae: Carex* sect. *Clandestinae: Carex capilliculmis* S.R. Zhang (≡ *C. filamentosa* K.T. Fu, nom. illegit.), *C. concinna, C. shaanxiensis* F.T. Wang & Tang ex P.C. Li, Asia (China), North America (Canada).

Comments — *Carex concinna* is a North American species, distributed in Canada and U.S.A. It belongs to section *Clandestinae* (= *Carex* sect. *Digitatae*) which includes ca 35 species from Europe, Asia, and North America, mostly from the temperate zone of Asia (Egorova 1999, Crins 2002, Dai et al. 2010).

Six *Anthracoidea* species are reported on members of sect. *Clandestinae: A. caricis* (Pers.) Bref., *A. humilis* Vánky, *A. irregularis* (Liro) Boidol & Poelt, *A. rupestris* Kukkonen, *A. shaanxiensis* (including *A. filamentosae* L. Guo), and *A. striata* H.C. Zhang & L. Guo. The morphology of the specimen examined here matches the description of *A. shaanxiensis,* recorded here for the first time from North America and on a new host plant. Previously, *A. shaanxiensis* has been reported only from Chinese localities: on *Carex shaanxiensis,* from Shaanxi Province, and *C. capilliculmis* (as *C. filamentosa*), from Gansu Province (Guo 2004, 2006).

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